Juice From Juice

Max Caplow, Ben Katz, Nanak Nihal Khalsa, Huck Phoenix

Wildwood School

Abstract

Throughout the project dubbed Juice from Juice our goal was throughout various tests was to create the most efficient dye sensitized solar cell possible. DSSC's use naturally occuring dyes and pigments as opposed to silicon, therefore reducing the production cost. However based on previous results, DSSC's have shown to be less efficient that standard solar cells, giving reason for us to begin this project. In order to provide variety in our data we decided to test a variety of different dyes as opposed to the standard extract from blackberry. We extracted xanthophyll from a yellow bell pepper, anthocyanin from raspberries, beta-carotene from carrots and we extracted chlorophyll from the leaves of an low light plant. After removing the pigments using hexane and acetone we made titanium dioxide covered conductive plates to absorb the various pigments so we could begin testing the plates. From our data collection we concluded the xanthophyll plates with three layers of titanium dioxide were the most efficient averaging at around 7% efficiency.

Introduction

The focus of this project was to design and test a Dye Sensitized Solar Cell (DSSC) with maximum conversion efficiency. DSSCs, which use metal oxides and pigments as opposed to silicon, reducing the production cost albeit with lower efficiencies. A variety of plant pigments were extracted and tested in these cells, specifically anthocyanin, xanthophyll, chlorophyll, and beta-carotene. The pigments were deposited onto layers of titanium dioxide deposited on conductive glass electrodes in order to make cells. These plates were tested to see how efficiently they converted incoming light into electrical power given variations in a number of parameters.

Apparatus – Test Circuit

An ammeter was attached in series to the DSSC and a potentiometer in order to record the generated current. In parallel to this circuit was attached a voltmeter in order to record generated voltage. The peak power in watts was as the product of the current and voltage while the resistance was changed in order to find the peak power output.

Apparatus

Of the plant pigments used in this study three: chlorophyll, beta-carotene, and xanthophyll were extracted using a mixture of hexane and acetone and one: anthocyanin was extracted using water. The plants used as pigment sources were carrots (beta-carotene), yellow peppers (xanthophyll), majesty palm (chlorophyll), and raspberries (anthocyanin). Glass, coated in a transparent layer of tin fluoride oxide (TFO) was coated with a layer of titanium dioxide (TiO2) and then sintered using a hot plate on high for thirty minutes. The plates were soaked in the dye mixtures for about five minutes in order to allow the pigments to bind to the TiO2 layer. Then another piece of conductive glass, which had an additional layer of conductive graphite was placed over the glass coated with TiO2 and was attached using binder clips. Iodine was applied in between the two pieces of glass using capillary action to act as the electrolyte.

Experimental setup

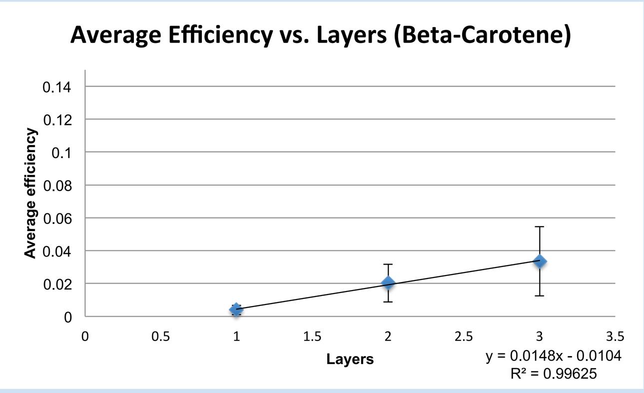
Pigment Extraction

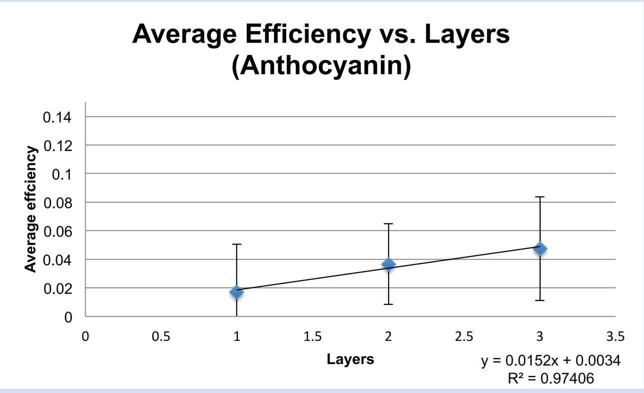
Two pigment extraction processes were used. For anthocyanin the pigment was extracted in water using a mortar and pestle. For chlorophyll, xanthophyll, and beta-carotene, the plant was mechanically crushed in acetone, in order to dissolve most of the organic matter, and then mixed with hexane to draw the active pigments in a separate layer for extraction.

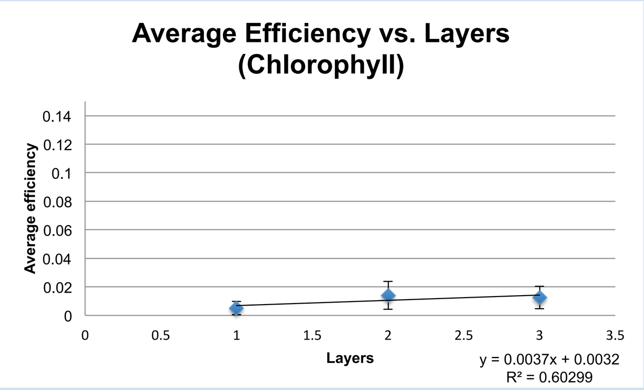
Plate Assembly

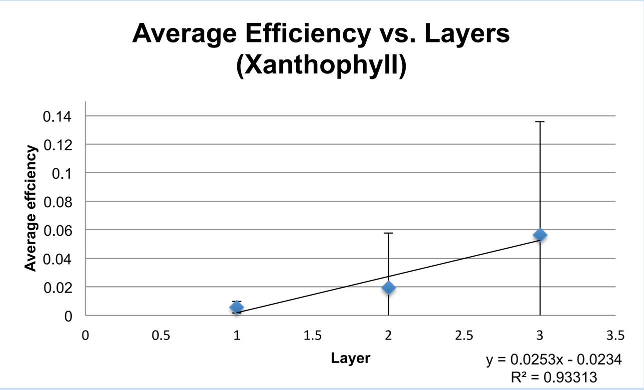
A layer of TiO2, of approximately 0.1mm thickness, is sintered onto conductive glass plates which act as the cell electrode. The number of layers was varied from one to three in order to study its impact on cell efficiency. A counter-electrode is then assembled with another piece of conductive glass covered in a thin layer of graphite. The cell is then assembled with the TiO2, pigment, and iodine between the electrode and counter-electrode and held together with binder clips.

Conclusion



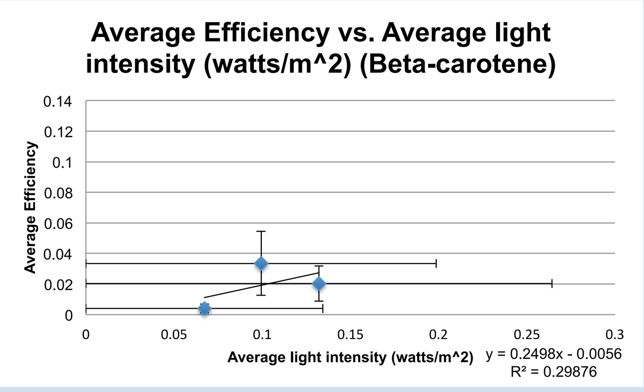


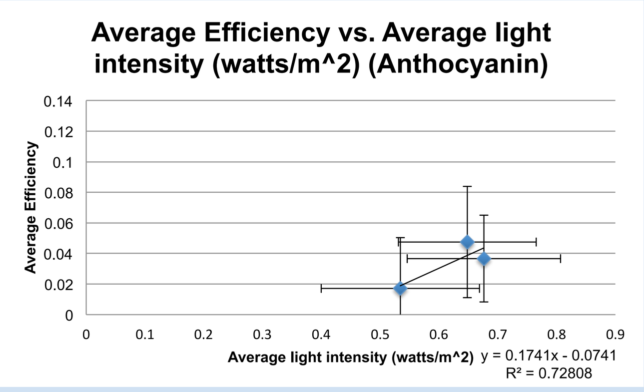


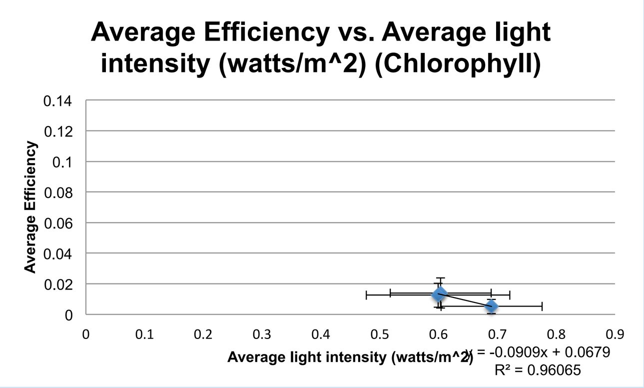


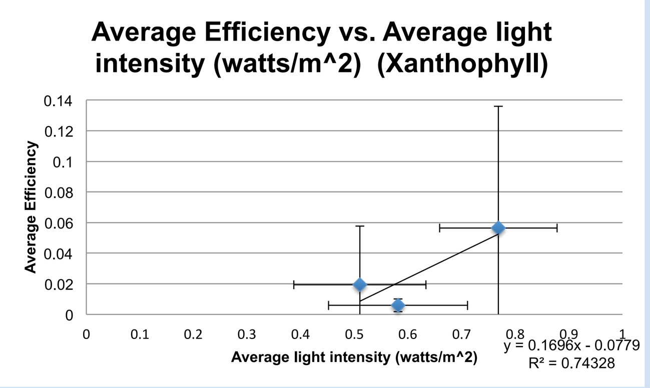
Layers

There is a positive linear correlation between cell efficiency and the number of TiO2 layers. The increase is almost perfectly linear and only chlorophyll countering this general trend.









Light Intensity

There is no definite correlation between the efficiency and the incident light intensity, at least below 1 Watt per square meter.

References and Acknowledgements

Acknowledgments:
The authors of this project would, first and foremost like to thank Ariel Levi Simons of the Wildwood School, as well as Will Harman and James Mckone from the California Institute of Technology, for their valuable input and guidance during this project. We would also like to thank Cal Poly SLO for the funding of this project.

References:

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[3] *Titanium Dioxide Raspberry solar Cell,* http://mrsec.wisc.edu/Edetc/nanolab/TiO2/index.html

[4] *ccisolar.caltech.edu* http://ccisolar.caltech.edu/images/energetics-DSSC.jpg

[5] *The potential of natural photosynthetic Pigments to Improve the Efficiency of Dye Sensitized Solar Cells* : Eran Barnoy, Mark Conley, A. Stephan Gan, Yoni Gefen, Jana Lovell, Katherine Mann, Adin Shuchatowitz, Christine Tobin ; Digital Repository at the University of Maryland

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Apparatus – The DSSC

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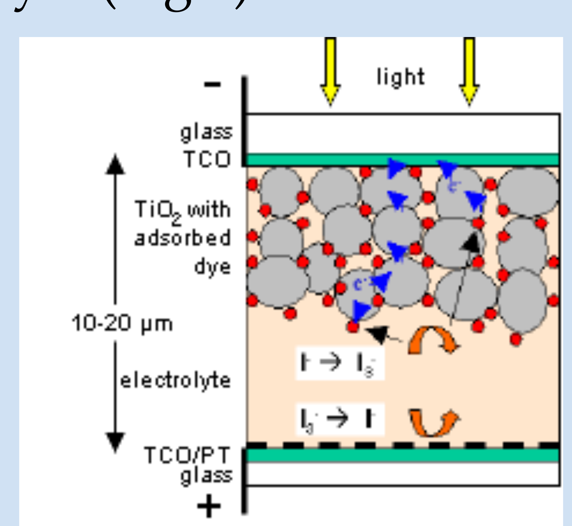


Fig. 1: Schema of dye-sensitezed solar cell

Apparatus – Test Circuit

An ammeter was attached in series to the DSSC and a potentiometer in order to record the generated current. In parallel to this circuit was attached a voltmeter in order to record generated voltage. The peak power in watts was as the product of the current and voltage while the resistance was changed in order to find the peak power output.

Experimental setup

In order to determine maximum power output for a DSSC the cell was first connected in series to an ammeter and potentiometer, which in turn was connected in parallel to a voltmeter (Fig 2). The resistance of the potentiometer was varied, with the resulting current and voltage of the DSSC recorded on a separate spreadsheet. To find the best power output we multiplied the current and the voltage, tuning the potentiometer to find the highest output.

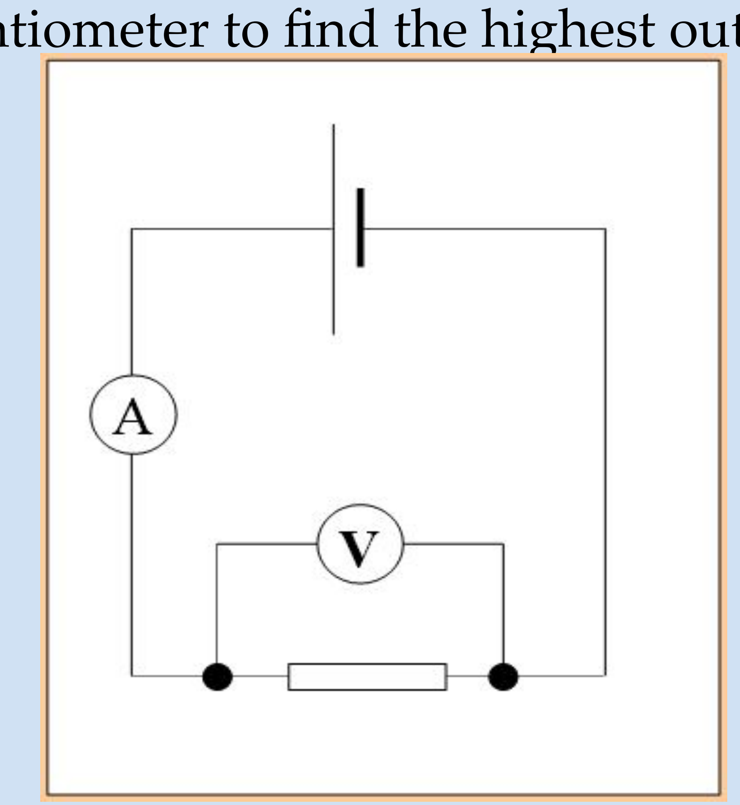
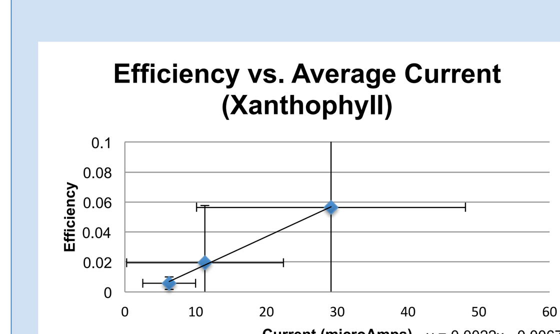
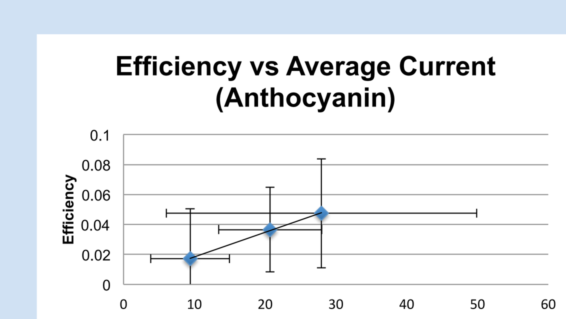


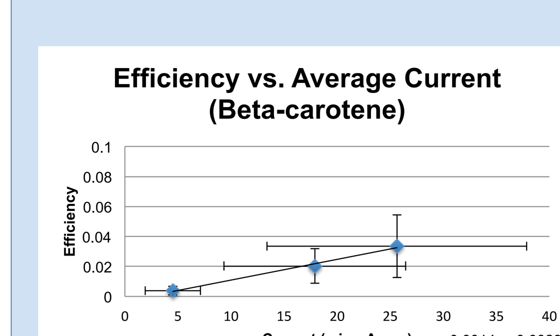
Fig. 2: Testing circuit to determine current/voltage of cells

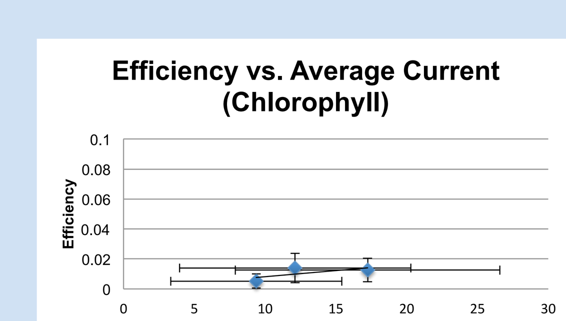
Results - Current

There is a strong positive correlation between cell current and efficiency, assuming a linear relationship, with an increase in current apparently driving an increase in efficiency.



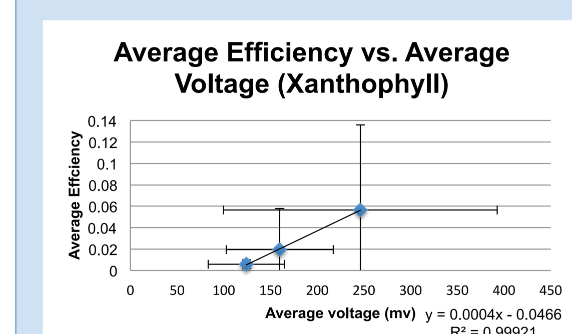


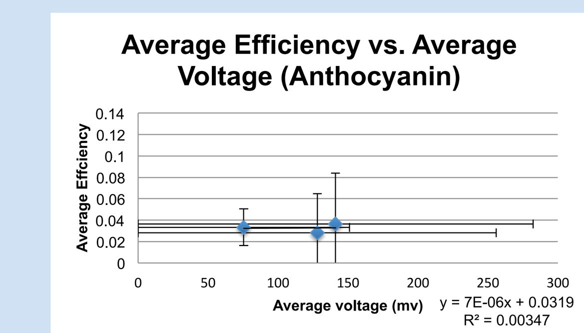


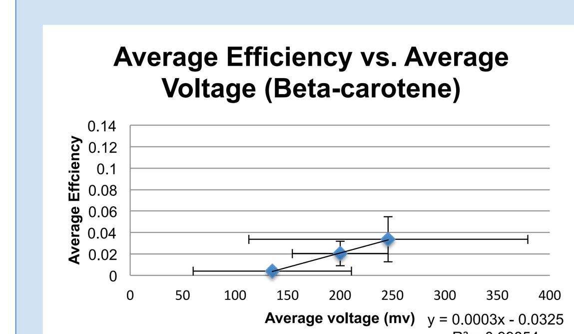


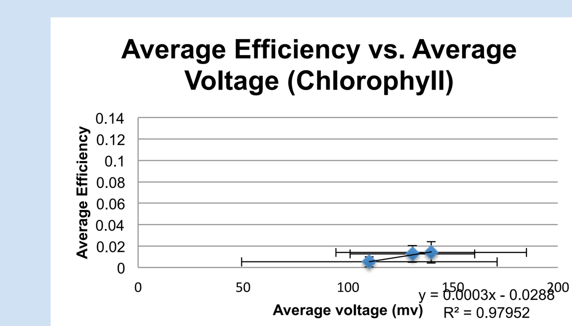
Results - Voltage

There appears to be a strong linear correlation between cell voltage and efficiency in Xanthophyll Chlorophyll, and Beta-carotene, but no correlation whatsoever in Anthocyanin.









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